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Topley, William

Gold and silver: their geological distribution...

Manchester

1887

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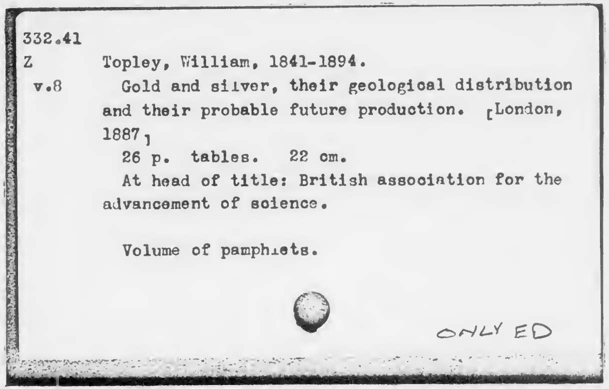

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Topley, William, 1841-1894.
Gold and silver, their geological distribution and their probable future production. [London, 1887]
26 p. tables. 22 cm.
At head of title: British association for the advancement of science.

Volume of pamphlets.

ONLY ED

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TECHNICAL MICROFORM DATA

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MANCHESTER, 1887.

Gold and Silver: their Geological Distribution and their Probable Future Production. By William Topley, *F.G.S., Assoc.Inst.C.E., Geological Survey of England and Wales, Recorder of Section C (Geology).*

[A paper prepared at the request of Section F (Economics)].

Amongst the numerous causes to which the recent depression of trade has been attributed that of variations in the production of the precious metals is on all hands allowed to be of importance. Economists differ as to the extent to which this variation influences prices, but all will allow that it has some influence; many believe that it is entitled to the first consideration.

It is, therefore, of interest to review the sources from which our present supply of gold and silver is obtained, and to ascertain (if possible) what is likely to be the supply in the near future.

Of late years the production of gold has declined. Is it likely that this decline will continue? If so, will it be rapid or gradual; or may there be periods of oscillation in an average gradual decline? Again, is it probable that the future production of gold will be chiefly from the old goldfields; or are these, as some believe, rapidly becoming exhausted, and must we look elsewhere?

As regards silver, for many years past there has been an increased annual production and a corresponding fall in value. This fall in the value of silver bears hardly upon countries where silver is the only standard of currency, and is especially disastrous in India. The question as to the probable future supply of this metal is therefore only second in importance to that concerning gold.

Questions of this wide character cannot adequately be treated in a short paper. All that I can hope to do, and all that is expected of me, is to treat the matter in general terms; to show where, and to some extent why, the supplies of the precious metals have varied in amount, and to indicate, if possible, where our future supplies may be looked for.

In place of long tables of figures, giving the yield of different countries, I have constructed diagrams. These have the advantage of presenting the general results at a glance, and of enabling us readily to compare one country, or one set of figures, with another. It may be objected that these diagrams do not give exact data; that the produce cannot be read off to within a few hundred thousand pounds. To this objection it is sufficient to reply that the pretended accuracy of figures given in published tabular statements has but slender foundation. For our Australian colonies and for Nova Scotia the yield of gold is fairly well known. Probably also the gold of the United States, of Russia, and that from metallurgical processes are known with sufficient exactness. But all other figures are simply estimates, often from very loose and insufficient data. The statistics of gold from vein-mining are more easily obtained, and are generally more accurate, than those relating to placer-mining; placer mines being generally spread over large areas, and in the hands of many sets of mining adventurers. The actual returns from mines will likewise be of varying value: where a duty has to be paid the return will be kept low; where a mine has to be puffed its 'returns' will be kept up. Again, in a large number of cases, the only estimate made is of gold exported, and this, even if correct in itself, may not fairly represent the yield of any one year.

Much information upon the production of gold and silver is contained in the 'First Report of the Gold and Silver Commission,' just published, and in the 'Report of the Commission on the Depreciation of Silver, 1876;' some also in the 'Report of the Royal Commission on Depression of Trade, 1886.' The fullest statistics are those of Dr. Ad. Soetbeer, a second edition of whose book appeared last year.[1] There are also the statistics prepared by the Mint authorities of the United States, and the general statistics collected by Jacob, Del Mar, and others.

Dr. Soetbeer's figures are those generally quoted; but those of Sir Hector Hay are evidently prepared with great care, and should be compared with the former.[2]

Mr. Stewart Pixley submitted a set of figures to the Gold and Silver Commission differing widely from all others. I have placed them on the following table, but have not elsewhere made use of them.

As indicating the uncertainty which hangs over this question, I give here these various estimates of the world's gold production for recent years:—

	Dr. Soetbeer (1886)	Sir H. Hay (1887)	Mr. S. Pixley (1887)
	£	£	£
1876	23,151,000	22,300,000	23,600,000
1877	25,033,000	23,400,000	15,200,000
1878	25,926,000	22,100,000	20,700,000
1879	23,340,000	20,800,000	13,100,000
1880	22,812,000	21,200,000	9,300,000
1881	22,162,000	20,600,000	9,900,000
1882	20,212,000	20,200,000	14,301,000
1883	20,164,000	19,600,000	7,700,000
1884	20,383,000	19,100,000	10,700,000

With variations such as these, it is evidently idle to trouble about fractions of a million in estimating the world's production; and for a similar reason, in considering the future supply, we need pay but little heed to a country where the production is below a quarter of a million, unless it may happen that several increasing countries may together amount to a sum which would have an appreciable effect upon the world's supply.

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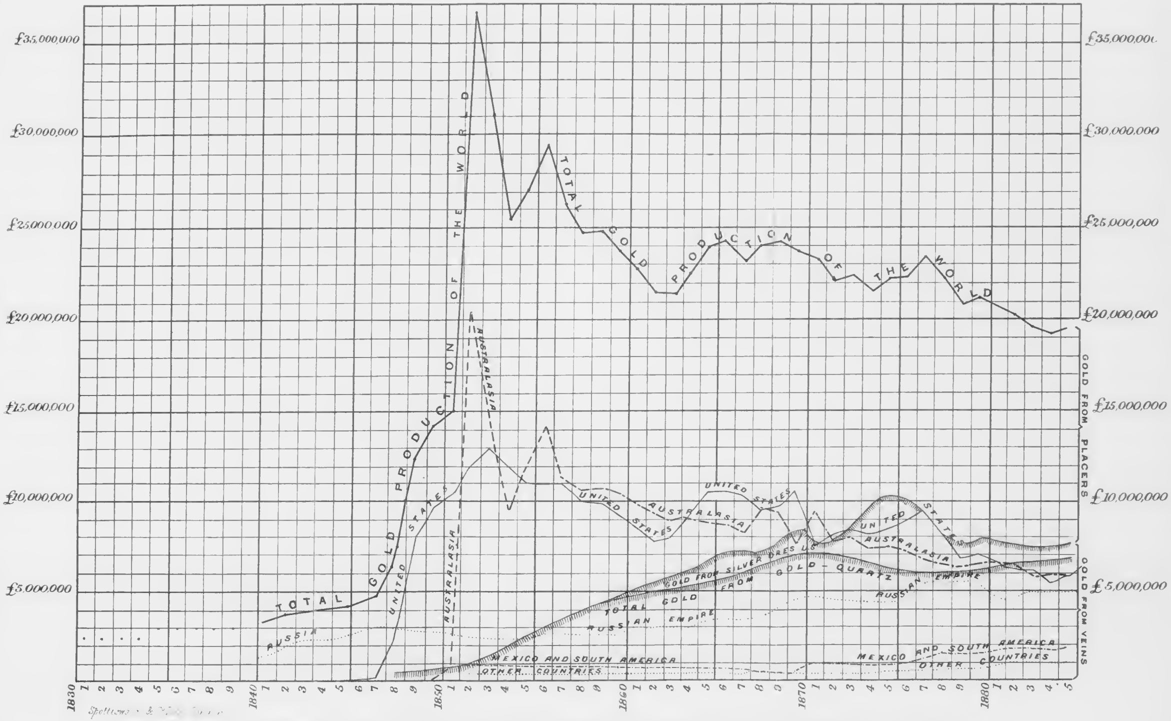
[1] *Materialien zur Erläuterung und Beurteilung der wirtschaftlichen Edelmetallverhältnisse und der Währungsfrage.* 4to., Berlin, 1866. With an Appendix of Diagrams.

[2] Sir Hector Hay's tables of 1887 give rather larger figures than those published by him in 1876. They have been revised to date by the best authorities obtainable.

TABLE I.

GOLD PRODUCTION OF THE WORLD

Shewing the Total Gold Production; the yield of the Chief Gold-producing districts, and (approximately) the Proportion of Gold obtained from Quartz and Placer mining, and from Silver-ores in the United States.



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Illustrating Mr. William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

It is important to bear in mind that the conditions under which gold has been obtained have varied much in different periods. In the early ages of the world gold was chiefly obtained by forced labour. African slavery was first employed by the Carthagenians in working the gold and silver mines of Spain; and centuries later the Spaniards revived this in working the gold and silver mines of the New World. Moreover, the influx of the precious metals which followed the discovery of Mexico and South America was due to gold already raised, and which was stolen from the natives, and not at first to actual mining by the invaders. The hands of Englishmen have not always been clean in dealing with native races, especially where gold has been concerned; but our record is honour itself when compared with that of those who preceded us in the New World.

Again, the great influxes of gold have come from the discovery and rapid development of alluvial deposits, which, in time, became exhausted; and a steady supply for the future must, for the most part, be sought for in ordinary mining, and in the metallurgical treatment of ores containing small quantities of gold and silver.

Another important point in regard to future supply is the improvement in mining, milling, and metallurgical processes.

In the ordinary methods of alluvial working there are considerable losses, and one source of future supply will be the re-washing of the waste workings of former years. The Californian method of Hydraulicking is the most complete plan for extracting a high percentage of gold from gravels, &c., but this can only be employed where large quantities of water are available at considerable pressure, and where the débris can be disposed of without injury to rivers and cultivated lands.

Mode of Occurrence of Gold.—Gold may be roughly classed under two heads, descriptive of its mode of occurrence:—1. In quartz-veins, cutting through the rocks, though occasionally almost coinciding with the bedding. 2. In detrital beds, derived from the denudation of rocks containing veins of auriferous quartz.

Veins of auriferous quartz rarely occur except in association with eruptive rocks; in the older rocks often with granites, and generally in association with dykes of diabase or diorite. So close is this association that we are led to believe that the eruptive rocks are the means by which the gold has been brought up towards the earth's surface, and from thence concentrated by slow aqueous action in the quartz-veins.

That such has been the origin of the gold and silver in the Comstock may now be taken as proved:—'The diabase shows a noteworthy contents in the precious metals, most of which is found in the augite. The decomposed diabase contains about half as much of these metals as the fresh rock. The relative quantities of gold and silver in the fresh and decomposed diabase correspond fairly well with the known composition of the Comstock bullion. The total exposure of diabase is sufficient to account for far more bullion than has been extracted from the mines. . . . Where ore is found in diorite, or in contact with it, it is usually of low grade, and its value is chiefly in gold. The notably productive ore bodies have been found in contact with diabase, and they have yielded by weight about twenty times as much silver as gold.'[1]

The greater part of the more productive auriferous veins are contained within Cambrian or Silurian rocks, generally in argillaceous strata or in alternations of slates and thin sandstones. But some veins are in Archæan rocks (S. America, W. of Lake Superior, and India); some in altered rocks, which are supposed to be of Triassic, Jurassic, or Cretaceous age. These newer rocks occur along mountain chains, where the beds have been greatly disturbed, folded, contorted, and faulted, and where rocks of very different ages occur close together. There are, therefore, frequently difficulties in deciding the exact age of gold-bearing rocks; but at present the evidence appears to be in favour of a great part of the rocks with veins of auriferous quartz along the western side of North and South America being of Secondary age.

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[1] G. F. Becker, 'The Comstock Lode,' *2nd Ann. Rep. U.S. Geological Survey*, 1882, p. 309.

The age of the rocks containing the veins does not decide the age of the auriferous veins themselves. Some veins of gold-quartz traversing the Archæan rocks of North America are pre-Silurian, because a conglomerate at the base of the Silurian rocks in Dakota contains gold; and also because in Canada the Silurian limestones rest horizontally upon the denuded edge of the Archæan rocks and of the auriferous quartz-veins. The Geological Survey of Canada is now engaged in mapping these areas; tracing the boundary of the Silurian limestone is important here in limiting the areas within which gold may be looked for. The auriferous quartz-veins of Australia, Nova Scotia, the Ural, and the Transvaal are post-Cambrian or post-Silurian in age, because they traverse Silurian rocks. In New South Wales, Queensland, and Nova Scotia they are, at least in part, pre-Carboniferous, because the lowest Carboniferous conglomerate lies on their edges and contains gold derived from them.

In the Transvaal some of the gold veins are pre-Devonian; they traverse Silurian rocks with intrusive granite and diorite. Resting on the denuded edges of the Silurian rocks, and at the base of beds believed to be Devonian, is a conglomerate containing gold. The Devonian rocks are themselves traversed by diorite dykes and by auriferous veins.

These general considerations supply a key by which the possible occurrence of gold in quantity, or rather its probable non-occurrence, may be anticipated. Gold occurs chiefly in quartz-veins in Cambro-Silurian rocks, or in rocks of other ages which have been, to some extent, altered from their original condition of soft sediment; but, as a rule, only where these rocks have been invaded by intrusive masses of igneous rocks—sometimes granite, but chiefly diorite and diabase. In ordinary fossiliferous Secondary rocks the occurrence of gold veins is unlikely.

In all gold-bearing districts disseminated gold may be expected to occur in rock newer than the auriferous veins; but with rare exceptions it is only where concentrated in gravel that the gold exists in payable quantity.

Gold generally occurs in quartz-veins in the free state; but it is often associated with various metallic sulphides—chiefly iron and copper pyrites. Even here it is probably in a free metallic state, but is so finely divided that its extraction is difficult. All vein-gold is subject to loss in stamping; but the losses in treating gold which occur with sulphides are often great. Much gold passes away in a finely divided state in the tailings, and there is a further loss in amalgamation in consequence of the gold not presenting a free metallic surface to the mercury. Then losses sometimes amount to about 70 per cent. of the total gold in the ore; it is frequently from 30 per cent. to 40 per cent. Recent improvements in mining and metallurgy have diminished the rate of loss, and from these improvements an increased yield of gold may be looked for.

Under this head of vein-gold should be classed the gold occurring with the ores of other metals in sufficient quantity to be worth extracting. In much of the silver ore of the Comstock, &c., the gold occurs to about one-third the total value.

Gold is widely distributed in iron pyrites, especially when this occurs in lode-like masses traversing the older rocks. Sometimes it is sufficiently abundant, either alone or in association with other metals, to pay well for extraction. Often, however, it is in too small a quantity to pay by any process at present known.

The pyrites at Rio Tinto contain from 8 to 11 grains of gold, and from ½ oz. to 1 oz. of silver per ton. This ore is essentially iron pyrites with a little copper pyrites. With the exception of small quantities obtained from some of the copper at Swansea, Widnes, and in Germany, this gold is entirely lost; yet Mr. J. H. Collins states that the pyrites raised yearly in the Sierra Morena contains a ton and a half of gold, or a money value of about 150,000*l*

There are other important mineral masses which must be classed with lodes, but which are extremely irregular in their mode of occurrence, and are very likely to diminish in productiveness in depth. There are the 'Bonanzas,' and similar rich masses of ore, which have yielded such vast quantities of silver and gold in the United States. In the Comstock, which is in many respects an exceptional area, the Bonanzas are enlargements of a quartz-lode along the junction-planes of eruptive rocks. As a matter of experience, it is found that these become less frequent and important at great depths.

Of different origin from these Bonanzas, but resembling them in containing large quantities of ore, are the chambers or pockets in calcareous rocks from which the greater part of the silver of the United States is now obtained. These are produced in the first instance by the action of atmospheric water dissolving away the limestone; into the hollows thus formed metallic ores have been subsequently introduced. Such chambers will therefore be unlikely to occur below the level to which surface waters have circulated. Sometimes, as in Nevada and Utah, there is no special relation between the country rock and the metallic contents of these chambers; but in other places, as at Leadville, in Colorado, the ores only occur where the limestone is overlain by eruptive rock.

The important bearing of these considerations on our present subject is this, that although it is not unlikely that great and irregular masses of rich silver or silver-lead ores may be again discovered, which may even for a time rival the past productiveness of the United States, yet it is improbable that any such rich districts will continue to be productive for a long period of time.

The opinion held in the early days of Californian mining, that lodes of gold-quartz diminish in production in depth, has been abundantly disproved. All lodes vary in productiveness in different places, and when in working downwards the lodes became impoverished, the workings were abandoned, and the miners transferred their energies to other lodes at the surface. But it is now known that such impoverishment is in most cases only local. If the lode be followed it generally regains its average productiveness. At the Adelong mine, New South Wales, payable quartz is raised from a depth of 1,030 feet. But it is in Victoria that the deepest Australian mines are found. In the Sandhurst district there are twenty-nine shafts over 600 feet deep, twenty-three over 1,000 feet, two over 2,000. The deepest is the Magdala mine (Ararat), the shaft of which is 2,409 feet deep.

A lode of the same average productiveness, however, may pay well in the upper part, but may prove unremunerative in the lower part, the actual yield of gold remaining the same. The general working expenses are far less for shallow mines than for deep mines. The lode is decomposed near the surface, and is more easily worked; the sulphides are also decomposed and the gold set free. In deep mines the sulphides are not decomposed, and there is an increased loss in stamping and amalgamating.

The second great division under which native gold may be classed is that of alluvial deposits, derived from the waste of rocks containing auriferous veins. The old conglomerates already referred to belong to this class; but their interest is scientific rather than practical, because they are too limited in extent to yield much gold, although generally worked for the metal where they occur.

The great alluvial gold deposits of the world are of newer Tertiary age. The older beds of California and Victoria are believed to be of about the age of our English Crag; but the evidence for this is by no means conclusive, and they may be of later date. Their great antiquity, however, is proved by—1. Their vast extent and thickness; 2. The great sheets of volcanic rock which cover them; 3. The enormous denudation which the gravels and the overlying sheets of basalt have undergone.

The modern alluvial deposits have been derived from the waste of these old Pleiocene (?) deposits; the gold has thus undergone a second concentration and the gravels are often proportionally enriched.

Alluvial deposits have hitherto yielded at least nine-tenths of the world's gold; in old times the proportion was higher. The enormous developments of gold-mining within short spaces of time, as in California and Victoria in 1849–52, were entirely due to alluvial mining.

In Russia, Siberia, and British Columbia almost the whole of the gold now produced is alluvial; but in Australia, the United States, and in South America vein-mining is increasing as the alluvial deposits are becoming exhausted.

United States.—Previous to the discovery of gold in California gold was produced in the United States in Georgia, North and South Carolina, Tennessee, Alabama, and Virginia: the total production of these States from 1804 to 1850 is estimated at $15,172,300, Georgia and North Carolina each producing over $6,000,000.

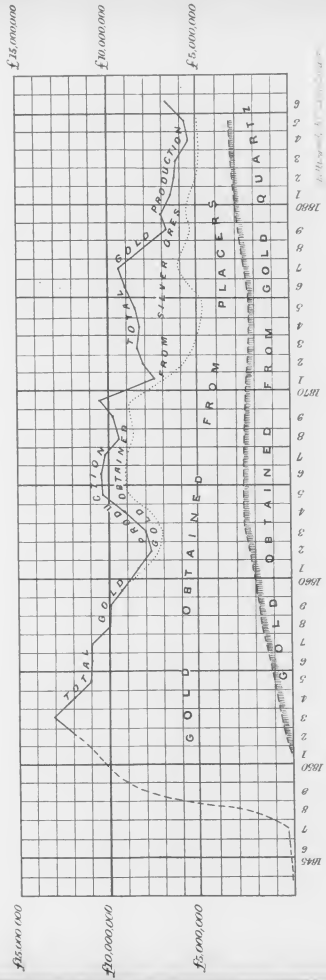
Before 1871 California stood at the head of the States in its output of the precious metals, but from 1871 to 1879 this place was taken by Nevada, in consequence of the immense development of mining in the Comstock area. In 1880 (census year) Nevada fell to the third place, having been passed again by California and also by Colorado, which then ranked first. In 1884 Nevada fell to the fourth place, having then been just passed by Montana, Colorado keeping its place at the top of the list. In 1885 the produce of Montana went rapidly ahead, whilst that of Nevada remained stationary.

The occurrence of gold in California was known to the Spanish Jesuit missionaries and to others, but it was not worked till 1848. So rapidly were the placers developed that in 1849 the production was 8,000,000*l.*, and in 1859 it rose to 13,000,000*l.* Gold-mining began in Oregon in

TABLE II.

GOLD PRODUCTION OF THE UNITED STATES

Shewing the Total Gold Production; the Gold obtained from Silver Ores, and (approximately) the Gold obtained from Placers and from Gold-Quartz Veins



Illustrating Mr William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production

1852; Arizona in 1858; Colorado in 1859; Idaho and Montana in 1860.

The chief gold-producing States after California are Nevada, Dakota, and Colorado. But up to the year 1880 California produced 50 per cent. of the gold of the United States, and 71½ per cent. of that obtained from placer mines; and even in 1885 it produced 40 per cent. of the total amount of gold obtained.

The following table gives the relative importance of the chief gold-producing States during the census year ending May 31, 1880:—

Range	Total value of gold in dollars[1]	Percentage production in relation to each State		Percentage production in relation to total production of the United States		
		Placer gold	Vein gold	Placer	Vein	Total
California	17,150,954 –	50·03	49·97	71·47	40·09	51·38
Nevada	4,888,247 –	1·02	98·98	0·41	22·64	14·64
Dakota	3,305,846	1·54	98·46	0·42	15·23	9·90
Colorado	2,699,900 +	3·77	96·23	0·85	12·16	8·09
Montana	1,805,764 +	64·40	35 60	9·68	3·01	5·41
Idaho	1,479,655 +	59·42	40·58	7·32	2·81	4·43
Oregon	1,097,700 –	84·39	15·61	7·75	0·80	3·29
Total	32,428,066	36·28	63·72	97·90	96·74	97·14
Other States	951,597	25·54	74·46	2·10	3·26	2·86
Total	33,379,663	35·97	64·03	100·00	100·00	100 00

Since 1880 *California* has decreased to $12,700,000, chiefly in consequence of repressive legislation as regards hydraulic mining. This decrease would be far greater were it not that quartz-mining has much developed. The Bodie district, in Mono county, for some years gave the chief supply of quartz gold; but this has fallen off in yield, and the supplies now largely come from districts further to the north-west.

The gold yield of California has oscillated in past years from causes unconnected with its own resources. In 1857 there was a rush to Fraser river, in British Columbia; in 1863 a great rush took place to Nevada, when from 15,000 to 20,000 people left the State. These variations in Californian produce are plainly seen in the total production of the country.

The great development of placer gold-mining in California was due to the introduction of 'sluicing,' or washing the gravel in trenches cut in the solid rock below. By this method deeper and poorer gravels could be worked than by the older Californian methods.

Sluicing, however, is no modern invention; it was employed by the Romans. In 1852 the system known as 'hydraulicking' was introduced, in which the gravel is worked by a stream of water forced against it under pressure. By this system a great part of the Californian gravels was worked up to January 1884. For years before that date there had been constant disputes and litigations between the miners, the farmers, and the owners of streams, because gold-working generally, but hydraulicking especially, had ruined large areas of land, had choked or diverted the streams, and had largely interfered with the channels of the navigable rivers. In January 1884 the famous lawsuit of Edward Woodruff *v.* The North Bloomfield Gravel Mining Company and six others was decided by the U.S. Circuit Court. The decision prohibited the defendants from 'discharging or dumping into the Yuba river, or into any of its forks or branches . . . any of the tailings, bowlders, cobble-stones, gravel, sand, clay, débris, or refuse matter from any of the tracts of mineral land mentioned in the complaint, and also from causing or suffering to flow into said rivers, creeks, or tributary streams aforesaid therefrom any of the tailings, bowlders, cobble-stones, gravel, sand, clay, or refuse matter resulting or arising from mining thereon. And also from allowing others to use the water supply of said several mines or mining claims, or any part thereof, for the purpose of washing into said rivers and streams any earth, rocks, bowlders, clay, sand, or solid material contained in any placer or gravel ground or mine.'[1]

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[1] Those marked + have since increased in yield; those marked – have decreased. Dakota remains practically unchanged.

This decree is sufficiently clear and definite, and from it there has been no appeal. As it stands, it practically puts a stop to systematic hydraulic mining in the basin of the Sacramento and San Joaquin.

The problem which engineers have to solve is whether means can be adopted for impounding the débris at the mines, and so preventing it fouling the streams. Various methods of doing this are under discussion, and upon their success depends the future of Californian hydraulic mining. The decree reserves to the court the power to modify or suspend the injunction 'upon any showing which the court may deem sufficient that the conditions have been so changed that the discharge of such mining débris . . . may be resumed or otherwise conducted so as not to create . . . or continue the nuisance complained of, or a nuisance of similar character.'

Official estimates widely differ as to the amount of material carried into the rivers by hydraulic mining. In the lower Sacramento basin, as a whole, the estimates for the year 1880 were 38½ and 53⅓ million cubic yards. In the Yuba river, to which the lawsuit especially referred, the estimates were 19 and 22⅓ million cubic yards.

The area affected by the mining débris was 43,546 acres, and the depreciation in value was estimated at $2,597,634. This district has yielded about $600,000,000 in gold.

The amount of capital invested in hydraulic mining in California is estimated at $100,000,000; the amount of payable auriferous gravel in the area covered by the injunction, and therefore closed, is estimated at 400,000,000 cubic yards.

There are some cases in which hydraulic mining is said to be a benefit to the lands lower down, by raising the level of the stream-beds, and therefore of the sub-surface waters; but in the vast majority of cases it is otherwise.

So far as the United States are concerned, it is only in California that legal restrictions of placer mining seriously affects the production of gold. It may hereafter do so in Oregon and Washington. But in many districts, as population increases and as interests other than mining become important, similar inconvenience will be felt, and doubtless with similar results.

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[1] See A. J. Bowie, 'Mining Débris in California Rivers,' *Trans. Tech. Soc. Pacific Coast*, vol. iv. Feb. and March 1887, from which the foregoing information on this subject is taken.

It is fortunate for the future of Californian mining that much placer gold is obtained by 'deep mining'—carrying levels at the bottom of the gravel beds, which often lie under a great thickness of lava. This process, however, is less productive of gold; it can only be profitably employed where the drift is deep and covered with volcanic rock, and where the rich ground is always at the bottom.

'The results of actual practice in Nevada county and elsewhere demonstrate that hydraulic mining, compared with drifting, employs twice the number of men and extracts four to six times the amount of gold per lineal foot of channel. The yield of the North Bloomfield Channel by drifting has been $150 per lineal foot of channel, while hydraulicking the entire deposit in this locality has given a yield of $750 dollars per foot' (Bowie, 'Hydraulic Mining,' p. 86).

The injunction against hydraulic mining applies only to the central counties of California, and in other parts it is carried on as usual. In the north-western part of the State it has of late years been developed; here the rivers flow direct to the sea through deep cañons, and hydraulicking does not harm the streams nor interfere with agriculture.

Colorado has increased from $2,700,000 in 1880 to $4,200,000 in 1885; this increase is mainly due to quartz-mining. The yield of gold in Montana has nearly doubled since 1880, the figures being in 1880 $1,805,764, in 1885 $3,300,000. Here, again, the increase has been mainly from quartz-mining, aided by an increased yield of silver containing some gold. In 1880, 64½ per cent. of Montana gold was from placers; in 1884 only 37 per cent. on a largely increased yield.

	1880			1884	
Placer	Vein	Total	Placer	Quartz	Total
$1,162,908	$742,856	$1,805,764	$800,000	$1,370,000	$2,170,000

There was a great rush to the Montana placers in 1862, some of the richest deposits in the world being then worked here; since 1862 over $150,000,000 of placer gold has been produced in this State.

Nevada, which once stood so high in gold produce in consequence of the Comstock,[1] fell in yield of gold to $4,888,247 in 1880, and to $2,000,000 in 1882. This was the lowest yield. It increased to $3,500,000 in 1884. The silver production of the State has continued to decline; very little placer gold is raised (only 1 per cent. in 1881), so that the increase is due to gold-vein mining.

Dakota is remarkably steady in its yield of gold, almost the whole of it coming from quartz veins in the Black Hill district, the placer gold being only 2 per cent. of the whole, and the silver produce practically *nil.*

Dakota is perhaps typical of the future gold-mining industry in the United States. Crushing and amalgamating processes are here carried to great perfection, so that low-grade ores are worked, and a large percentage of the gold value obtained. The average yield of the lodes is only $4 per ton; but ore of only $2 per ton is worked at a profit, the expenses of mining and milling being less than $1 per ton.

Oregon declined in yield of gold from $1,097,700 in 1880 to $660,000 in 1883 and 1884; it increased to $800,000 in 1885. The greater part of this is from placer mines, vein-mining having been as yet but slightly developed. It is believed that the production of Oregon is underestimated.

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[1] Mr. Del Mar estimates $18,002,906 gold and $20,570,078 silver from the Comstock in 1876. The total yield from 1859 to 1880 was about $140,000,000 gold and $175,000,000 silver.

Idaho varies very little in its production of gold, but has somewhat increased in silver. About 60 per cent. of its gold was from placers in 1880, probably rather less than this now.

In *New Mexico* the yield of gold increased from $49,354 in 1880 to $300,000 in 1884, and to $800,000 in 1885; the silver produce has likewise increased, but not in the same proportion. No record of placer workings could be collected during the census year, and it was believed that the amount of gold so obtained was very small. Rich placers were, however, known to exist, and have since been worked. The increase is therefore largely due to this cause.

Arizona, which produced only $212,000 in gold in 1880, increased this to over $1,000,000 in 1881 and 1882; but the yield afterwards fell, and was only $800,000 in 1885. Only 14 per cent. of the yield in 1880 was from placers; the proportion must be considerably less now, the developments of late years having been chiefly in vein-mining.

The remaining States call for no special remark, their total yield of gold in 1885 having been only $1,020,000. Utah ($120,000 in 1885) is interesting from its steady yield of gold, over 90 per cent. of it being from veins.

The general result of this inquiry is to establish the important fact that so far as the United States are concerned the gold supply is steadying, with a slight tendency to increase; we may expect this steady yield to continue, because it is due in an increasing proportion to vein-mining. Placer-mining yielded 36 per cent. of the gold in 1880; only about 30 per cent. in 1885.

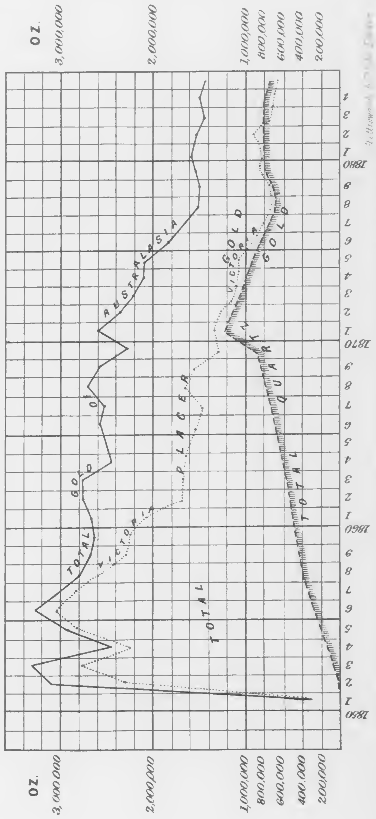
Mr. A. Williams in his 'First Report on the Mineral Resources of the United States' (1882) makes the following remarks on the probable future production of the United States; remarks which the succeeding four years have well justified:—'From the foregoing figures [statistics of production] the general deduction may be drawn that the annual precious metal output of the United States during recent years may be stated at between $70,000,000 and $80,000,000, coining value, and that the fluctuations in the proportional amounts of gold and silver are greater than those of the total product. It is also safe to assume that this rate of production will be maintained for some time to come, and that the probability of a slight increase is greater than that of a decline. Experience has shown that old localities become exhausted, or fall off in their rate of production; new localities are developed which fully take their place; and that the general result is therefore nearly uniform as compared year by year. By the time the country has been thoroughly explored for gold and silver deposits—a time which may be considered as indefinitely remote—the facilities for mining and working the ores will undoubtedly be such as to enable systematic and permanent development to be maintained in places and with ores which at present could not be profitable.'

Victoria.—Gold was discovered in Victoria in 1849. It was re-discovered in 1851. There was then a rush to the alluvial workings, and the yield suddenly rose from about 200,000 oz. in three months of 1851 to 2.286,000 oz. in 1882; the maximum yield in 1856 was 3,053,744 oz The total yield of Victoria up to the end of 1885 is estimated at 53,750,000 oz., valued at 214,000,000*l.*, or an average of 4*l.* per oz.

TABLE III.

GOLD PRODUCTION OF AUSTRALASIA

Shewing the Total Gold Production (in Ounces), the Gold obtained from Placers and from Gold Quartz (approximately) and the Gold Production of Victoria.



Illustrating Mr. William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

In the early days of gold-mining in Victoria almost the whole yield was from placers. The relative proportions of quartz and placer gold is not known before 1868; in that year the amounts raised were 1,087,502 oz. of placer gold, and 597,416 oz. of quartz gold. From this date the yield of alluvial gold steadily fell to 1878, when only 264,453 oz. were raised, or one-fourth of that raised in 1868.

Alluvial and vein gold were about equal in 1871. The maximum quantity of vein gold was raised in 1872; the minimum quantity in 1879. For the last four years the average proportions have been about 40 per cent. alluvial gold and 60 per cent. vein gold, and these figures fairly represent the proportions for the whole of Australasia in 1883; but the rapid increase of vein gold in Queensland is now increasing the percentage from that source. From the great importance of Victoria it may be as well more fully to tabulate the facts just given :—

	Alluvial Gold	Quartz Gold		Total Value
	oz.	oz.	Per cent.	£
1856	—	—	—	12,214,576
1868	1,087 502	597,416	35·5	6,739,672
1871	698,190	670,752	49·7	5,475,768
1872	639,551	691,826	52·0	5,325,508
1878	264,453	493,587	64·7	3,032,160
1879	293,310	465,637	61·5	3,035,788
1882	352,078	512,532	59·3	3,458,440
1884	307,533	471,085	60·6	3,114,472
1885	—	—	—	2,940,872

The Ballarat district makes the greatest return, producing about one-third of the total yield of Victoria, 64 per cent. of its gold being alluvial; the Sandhurst district comes next, producing one-fourth of the total gold, but only 3 per cent. of its yield is alluvial. The other districts stand thus in relative importance (the percentage of *alluvial* gold in each being also roughly stated) :—Castlemaine (34); Maryborough (75); Beechworth (62); Ararat (61).

The rapid development of gold-mining in Victoria and its sustained importance were due to working the shallow and rich alluvial deposits; but these became exhausted, and the produce had to be raised from the deep placers, often underlying a great thickness of basalt. Many of these 'deep leads' are now being worked at 400 and 500 feet below the surface.

'Tens of thousands of pounds are frequently expended before the deep alluvial mines become remunerative, and sometimes after all failure is encountered; but, nevertheless, successes have, in the main, counterbalanced the failures, and increasing experience tends to lessen the risk of the latter. There are still hundreds of miles in length of unworked leads which are likely to reward future enterprise. No great discovery in shallow ground has been made for the last ten years, nor can such be now expected, as no large area of possibly auriferous shallow country remains untried.'[1]

Queensland is, next to Victoria, the most important British gold-producing colony, and it is of especial interest, because the yield of gold is now increasing. In 1867 the yield was under 50,000 oz., in 1868 it rose to 165,000 oz., varied till 1873 (195,000 oz.), and then suddenly rose

[1] *Illustrated Handbook of Victoria*, Col. and Ind. Exhib. 1886, pp. 80, 81.

to 375,000 oz. in 1874, attaining to its maximum of 391,515 oz. in 1875. This sudden rise was due to the rush to the Palmer goldfield and to the rich alluvial ground there worked. The yield fell gradually to 212,783 oz. in 1883; it rose to 307,804 oz. in 1884, and to 310,941 oz. in 1885.

Queensland is now essentially a quartz goldfield. In 1880 the Palmer and other alluvial districts had declined in yield; that from quartz had increased; so that about 65 per cent. of the total yield was in that year quartz gold.

In 1885 the Charters Towers and Cape River goldfield alone produced 43·6 per cent. of the total yield, the Gympie goldfield 28·8 per cent.: these are now almost entirely quartz fields.

The Charters Towers field is especially important. In 1883 its yield was 69,555 oz.; in 1884, 109,335 oz.; and in 1885, 134,650 oz. The amount of gold in the quartz is also increasing as the veins are followed in depth. In the earlier days of mining it was from 1½ oz. to 1¾ oz. per ton; it is now close upon 2 oz.

Queensland is also remarkable for the Mt. Morgan goldfield, where the gold occurs impregnating a mass of ferruginous rock, and an iron-stained siliceous sinter, which, with the gold, is supposed to have been deposited by geyserian action. The mass is worked as an open quarry. It contains on an average 7 oz. of gold per ton; the hæmatite contains 3¼ oz.; the sinter 10½ oz.; but only about one-half of the gold present can be extracted. The tailings are stored for future treatment. The Mt. Morgan gold is the purest known, its value being 4*l.* 4*s.* 8*d.* per oz. Its fineness is 997, the rest is copper, with a little iron. In all other native gold silver is the chief accompaniment, but in the Mt. Morgan gold there is only a very minute trace. The gold from Mt. Morgan does not figure in the Queensland official returns, it being sent direct to the mint at Sydney.

In *New South Wales* gold was worked in 1851, 144,120 oz. having been raised in that year. This colony reached its maximum the next year (1852), when 818,751 oz. were produced. The yield fell to 171,367 oz. in 1855; in 1858 it rose to 286,798 oz. From that date to the end of 1875 it oscillated much, the greatest amount being 640,622 oz. in 1862, the least being 240,858 oz. in 1870, and 230,883 oz. in 1875. Since 1875 the yield has much decreased, and was only 103,736 oz. in 1885.

The decline from 1884 to 1885 (3,453 oz.) is attributed in the official report 'wholly or mainly to the drought.' It is also stated that some amendments to the Mining Act were made in 1884, which it is hoped will lead to the reworking of some of the abandoned mines, which, it is thought, may prove remunerative if worked on a large scale with system and economy.

The average yield of quartz raised per ton was 1 oz. 12 gr. in 1885, as compared with 14 dwt. 10 gr. in 1884. This was due to the improved quality of the quartz raised in the southern and New England districts. As the average yield per ton was greater in 1885 than in 1884, whilst the total amount of gold produced was less, it follows that the amount of quartz raised was very much less; in fact, it was little more than one-half; indicating a more rapid fall in quartz-mining than is apparent in the returns generally quoted.

In 1880 about 29 per cent. of New South Wales gold was from quartz veins; in 1882 about 25 per cent. The average value of New South Wales gold has been 3*l.* 14*s.* 6*d.* per oz.

It is probable that the future importance of New South Wales as regards the precious metals will depend largely upon its silver. The ores chiefly occur towards the northern and western parts of the colony, the latter being that most recently becoming of importance. All accounts agree in the richness of the ores and in the extent of the argentiferous area.

The following figures show the recent production :—

	Silver		Silver-lead Ore			Total Value
	Oz.	Value	Tons	Cwt.	Value	
		£			£	£
1881	57,254	13,026	52	14	1,625	14,651
1882	38,618	9,024	11	19	360	9,384
1883	77,065	16,488	136	4	2,075	18,563
1884	93,660	19,780	9 167	11	241,940	261,720
1885	794,174	159,187	2,286	0	107,626	266,813

South Australia has never yielded much gold. But there was a fairly steady rise to its maximum of 21,454 oz. in 1884,[1] then a sudden fall in 1885 to 4,694 oz., its lowest yield since 1873. The average value of South Australian gold is 3*l.* 9*s.* 4*d.* per oz.

It is known that there are unworked alluvian deposits and reefs in the northern territory, which the new railway may open up, and which may for a time somewhat increase the yield of gold.

The first return for *New Zealand* was in 1857, when 10,437 oz. were obtained; the yield fell to 4,538 oz. in 1860, and then rapidly rose to its maximum of 735,376 oz. in 1866.[2] Since that date there was a fairly steady decline to 1884, when the yield was 229,946 oz., which increased to 233,068 oz. in 1885. The average value of New Zealand gold is 3*l.* 18*s.* 4*d.* per oz.

The yield of gold in New Zealand has remained much more steady than in the other Australian colonies, with the exception of Queensland. It now yields only a little less than one-third of its maximum, whereas Victoria now yields less than one fourth and New South Wales less than one-sixth.

Almost one-half of the New Zealand gold is now obtained from quartz, 111,432 oz. having been so obtained in 1885; an increase of 23,000 oz. over the quartz gold of 1884.

From this fact, and from the known occurrence of unworked reefs, there is reason to hope that the yield from quartz-veins may continue steady even if it does not increase.

Gold-mining in New Zealand is interesting from the application of electricity to quartz-crushing. At the Phœnix Quartz-mining Company, Otago, water power is used to drive two Brush dynamos, each transmitting

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[1] These figures give the amount of gold received at the various Australian mints from South Australia, and possibly are under-estimates.

[2] I take these figures and many others relating to Australasia from the 16*th Ann. Rep. of the Deputy Master of the Mint* (1886), giving a complete table of Australian produce to the end of 1884. Dr. Hector's diagrams, published in the 3rd edition of his *Handbook of New Zealand*, 1883, shows the maximum yield in 1871. These diagrams distinguish the alluvial and the quartz gold in each of the four districts into which New Zealand is divided.

36 horse-power to the stamps two miles away. This is said to work well, and if fully successful here will doubtless be turned to good and profitable account in other places where the water power is not conveniently situated for crushing.[1]

In *Tasmania* gold was discovered in 1852, and quartz-mining began in 1859; but the yield must have been small, as in 1866 the production was only 348 oz. It varied up to 11,107 oz. in 1876, falling to 5,777 oz. in 1877. The discovery of the Lisle alluvial deposits raised the yield to 25,249 oz. in 1878, which increased to 60,155 oz. in 1879. This was the maximum year. The yield has declined to 41,241 oz. in 1885.

Taken on the average of the twenty years 1866–85, the alluvial gold has been only 33 per cent. of the total amount, the Lisle and West Coast districts (both entirely alluvial) together producing 20 per cent. of the total amount. In 1885 the alluvial gold was only 19 per cent. The average value of Tasmanian gold has been 3*l.* 18*s.* per oz.

The gold yield of Tasmania is small, but is subject to less fluctuation than other goldfields; its present yield is more than two-thirds of its maximum. This steadiness is due to the large proportion of vein gold. Unless the accounts of the newly discovered 'Iron Blow' are grossly exaggerated, we may expect that the yield of vein gold will now increase.

As regards Australasia, the general result may be stated as follows. Although Victoria still holds the first place, and may do so for some years to come, there is some probability of it being deposed from this position of honour in favour of Queensland, the vein gold from which is increasing in amount, and is likely to do so still more. With a probable increase in New Zealand, and much placer gold still unworked in Victoria, it is likely that the total produce of Australia will, for some time to come, not fall below 5,000,000*l.* per year.

A fact of some interest, and not yet explained, is the decrease in the fineness of Australian gold as we pass from south to north, due to the increased amount of silver in it. The same thing occurs in New Zealand. This generalisation, however, does not hold in North Queensland. Apart from the Mt. Morgan deposit, which is remarkably pure and is in every way exceptional, we find that the gold of North Queensland is finer than that in the south of the colony.

Canada.—The chief gold-producing districts are *British Columbia*—almost entirely alluvial, and *Nova Scotia*—almost entirely veins. Alluvial gold has long been worked in Quebec, in the Chaudière valley, but no serious attempt has yet been made to work the quartz veins which are known to exist here in the Silurian rocks. Gold occurs in the gravels of the Saskatchewan, and is apparently most abundant near Edmonton. As no gold has been found in the streams coming from the Rocky Mountains the origin of the gold must be looked for elsewhere; it is supposed to lie in the great drift deposit which forms the prairies, and which has been largely made of the waste of the Archæan rocks to the N. and N.E. Near the Lake of the Woods auriferous quartz veins occur, but only near the contact of the Laurentian granitoid gneiss with intrusive schistose hornblende rocks; bosses of intrusive granite occur in the district. Silver occurs in these veins, sometimes in greater proportion by weight than gold.[1]

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[1] *Report* [to New Zealand Parliament] *on the Mining Industry of New Zealand*, 1887, p. 83.

British Columbia.—Gold is chiefly found in the alluvial beds of the Rocky Mountains, in the Purcell, Selkirk, Gold, and Cariboo ranges, which run parallel to, but west of, the main ridge. The discovery of alluvial gold in the Fraser river drew away many miners from California in 1857–9. In 1860 the Cariboo district was discovered, and this has been the most continuously productive. Up to the end of 1885 about 10,000,000*l.* of gold were produced, three-fifths of which came from the Cariboo district. Good alluvial ground has been found on the Wild Horse creek (Skirmish river of Palliser), derived from the waste of quartzites, schistose rocks, and argillites, with some compact greenstones probably interbedded; the gold is worth 3*l.* 16*s.* per oz. Rich placers have recently been discovered on Granite creek.

Practically the whole of the gold yet produced in British Columbia is alluvial. No doubt some productive gold-bearing veins will be discovered, but it seems unlikely that they will yield a large supply.

The gold statistics of British Columbia are very untrustworthy, as no official records have been kept.[2] The maximum yield was, probably, in 1864 (778,000*l.*); it fell, with various oscillations, to 280,000*l.* in 1881, and then gradually declined to 140,000*l.* in 1885. The fluctuations in yield are partly due to the seasons, heavy floods in the spring being disastrous to placer mining; but the fall is due to the exhaustion of the placers with no compensation in the development of vein mining. Some revival may be looked for from the systematic adoption of hydraulic mining, as in some places only the sides of the valleys have yet been worked.

British Columbia is placed at a great disadvantage for gold-mining as compared with California. In California the sheets of volcanic rock have preserved large areas of rich placer gravel from denudation; the modern streams have cut their way through these old gravels, enabling them to be mined without great trouble from water, and affording every facility for drift-mining, and, where otherwise convenient, for hydraulic mining. The waste of the old placers has rendered the modern alluvial gravels very rich in gold.

In the Cariboo district of British Columbia the streams have not cut their way through the older placers into the bed rock. From 50 to 150 feet of the richest auriferous gravel lies beneath the stream beds. All the rich placers of the Cariboo have been mined by underground drifting with all the difficulties of water and 'slum' to contend with overhead. At Omineca and Cassiar, lat. 55° to 57°, the auriferous gravel is in perpetually frozen ground; the working season lasts only two months in the year.[3]

Nova Scotia.—It was formerly supposed that the auriferous quartz of Nova Scotia was interstratified with the Lower Silurian (Cambrian) rocks, and that the gold had been derived from the underlying Laurentian rocks. It is now known that this was a mistake; the quartz-veins run in a general way along the lines of bedding, but they cut across the beds, and are certainly of later date.

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[1] A. C. Lawson, 'Lake of the Woods Region,' *Geol. Survey of Canada*, Ann. Rep., N.S. i. 1885.

[2] It is believed that a small part of the placer gold from Alaska is carried over the frontier, and is returned as produced in British Columbia.

[3] A. Bowman, *Trans. Amer. Inst. M. E.*, 1887, p. 716.

Practically the whole of the gold of Nova Scotia is raised from quartz-veins; the denudation of the gold-bearing rocks must have produced a vast quantity of alluvial gold, but this is now mainly dispersed over the bed of the Atlantic,[1] although it is likely that some gold may be found beneath the alluvium of the valleys near Halifax. Gold was discovered in 1859; in 1862 over 7,000 oz. was raised, 14,000 oz. in 1863, 20,000 oz. in 1864, and 27,000 oz. in 1867: this was the maximum yield. Since 1871 it has ranged from 11,000 to 16,812 oz., with the exception of one year (1874) when it fell to 9,140 oz. The steady increase of late years is noteworthy:—

Year	Total ounces of gold extracted			Stuff crushed	Yield per ton of 2,000 lbs.	
	oz.	dwt.	gr.	tons	dwt.	gr.
1881	10,756	13	2	15,556	12	20
1882	14,107	3	20	22,081	12	18
1883	15,446	9	23	25,954	10	21
1884	16,059	18	17	25,147	12	18
1885	22,203	12	20	28,890	15	4
1886	23,362	5	13	29,010	16	2

The increase in 1886 as compared with 1885 is chiefly due to the opening of new mines and to the yield in 'unproclaimed' districts; some of the older districts fell off considerably. The gold mainly exists in the free state, and generally in quantities visible to the eye. But the veins also carry sulphides which include a considerable amount of gold. Most of this gold passes into the tailings. 'Assays show that these tailings when concentrated are often rich enough to warrant attempts being made to save the gold; but hitherto no systematic attempts have been made in this direction.'[2]

Although interesting to us the gold of Canada has no great influence on the world's production. In 1864, following the great rush to the Fraser river, British Columbia ranked, after California, with the best of the American States; but it now would take only the tenth place, and Canada, as a whole, would only take the seventh place.

Russia.—The large amount of gold obtained since 1851 from the United States and from Australia leads most people to pay but small heed to Russia as a gold-producing State, but this is a grave mistake. During the few years preceding the great gold discoveries Russia (including Russian Siberia) was the chief gold country of the world; and notwithstanding the great output of other districts the variations in its yield have had a perceptible influence upon the world's production. The maximum yield was, in 1879, 5,942,000*l.*; the yield fell to 4,561,000*l.* in 1882, but rose again the next year, and was 4,980,000*l.* in 1884.

The history of Russia's gold production is shown on Table I.; when compared with the production of the other great gold countries its uniformity is very striking. This is the more remarkable because almost the whole of Russian gold is obtained from placer workings, quartz-mining being mainly confined to the south-eastern slopes of the Ural Mountains. The reason of this uniformity of yield is the vast area over which the workings extend. The yields of the various districts have varied much, but the average production of the whole is fairly steady.

Since 1829 Siberia has been the chief source of Russian gold. From 1867 to 1874 it yielded from two-thirds to three-fourths of the total amount.

In 1860–67 the Ural district yielded about 20 per cent. of the total production; in 1872 this fell to 17½ per cent., and in 1877 to 16 per cent. Since that date it has still further decreased. The yield of eastern Siberia has risen, and in 1877 amounted to 78 per cent. of the whole.

The modern developments of Russian gold-mining have been in the extreme east, in the basins of the Amur and the Lena; here, as elsewhere in Siberia, entirely in alluvium. Much of the ground is perpetually frozen, and has been so probably since the Glacial period. This frozen condition of the gravels has protected them from denudation; but for this much more would have been swept into the sea by the summer floods. The preservation of the Siberian placers is thus due to frost; those of the Californian and Victorian placers to volcanic action.

The vast extent of unworked placers in eastern Siberia will yield a steady supply for many years to come. But the older placer workings in other areas will fall off in yield, and therefore it would not be safe to anticipate a yearly increase to the world's annual production from this source. There is one point, however, to be borne in mind. The source of the gold must be in the Altai and in the ranges of mountains to the east. All this is practically unexplored; and we may fairly anticipate the discovery here of quartz veins, which will probably help to keep up the supply of Siberian gold when the yield from the placers decline. Very little is known of the geology of this region, but the existence of Silurian rocks has been proved.

African Gold Coast.—This has long been known as a source of gold, and the amount of the metal thence exported must in the aggregate have been very considerable. There are no means of ascertaining the amounts obtained, and hence the wildest estimates are made.

It has been stated that Western Africa during part of the last century produced over 3,000,000*l.* of gold yearly. Similar estimates have been made for South-eastern Africa during the Portuguese rule. But Dr. Soetbeer's estimate for the whole of Africa is a yearly average of 279,000*l.* from 1701 to 1740, and of 209,250*l.* from 1741 to 1800. It is probable that the yearly production of the whole world during the last century rarely exceeded 3 000,000*l.*, and that only during the maximum period of the Brazilian placers. We need not, however, doubt the existence of rich alluvial tracts in Western Africa, which, after having been drawn upon for centuries by hand labour, may yet for a while yield considerable supplies if systematically worked. There must be numerous auriferous reefs the denudation of which has yielded the gold of the river gravels and of the seashore. Some of these have long been known, and a few partially worked, and from them hereafter a somewhat increased yield for West Africa may be expected.

The quantity of gold exported from the British possessions at the Gold Coast during 1884 is officially stated at 24,994 ounces, valued at 89,981*l.*

South Africa.—No trustworthy data are available for ascertaining the yield of gold in South Africa, and the accounts of the value of the gold-producing areas are very conflicting. Some look to South Africa as a district which will soon rival California and Victoria; but there is no evidence that such a future is before it. There are numerous reefs of auriferous quartz, some apparently along the bedding of the rocks, others cutting across the bedding: these auriferous veins are associated with intrusive diorites.

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[1] An interesting example of placer of Carboniferous age occurs at Gay's river. This has been worked to a small extent. (H. S. Poole, *Q.J.G.S.* vol. xxxvi. 1880, p. 313).

[2] E. Gilpin, *Report Dep. Mines, Nova Scotia*, &c., 1885.

No important areas of alluvial gold-bearing gravels are known, although most of the gold obtained up to within the last few years was alluvial. The future of South African gold-mining depends upon quartz veins. The veins yield gold of rather more than average purity and quantity. At present only the richer veins are worked, but with improved methods and machinery much of the poorer ore can be treated, which will increase the total yield whilst reducing the percentage. So far as yet worked, the gold of the veins is mostly free; the losses in working should therefore be less than in most other vein-areas, or than probably will be the case when the veins are followed to the deep.

A steadily increasing yield of gold may be looked for from this area, but, so far as we yet know, not in sufficient amount to be of importance in the general stock of the world. Much of the Transvaal gold passes through Natal; the value thus exported was 6,865*l.* in 1885, and 52,222*l.* in 1885.

India.—Although gold occurs in many parts of India, it is only to the southern part of the peninsula that people look who have great hopes of a large gold supply. Probably these hopes are less high and less generally felt than they were a few years back. There are no deep placers, such as have yielded the vast supplies of Victoria and California; the shallow alluvial deposits, often locally very rich, have been in great part exhausted, and for the future supply of Indian gold we must look to vein-mining. The Wynaad and Mysore are the districts most likely to yield the future supply. In the former the gold is often associated with sulphides, and hence there is much loss in working. In Mysore the gold is more often free. Kolar is supposed to be the district which yielded the chief supply of gold to the native princes in past times, and it gives some promise of supply for the future.[1] But there is no probability that it, or any other part of India, will rise to a high rank as a gold-producing country. Nothing is officially known as to the exact amount of gold produced in India at the present time.

The amount of gold raised in *China* is certainly large, but its value is unknown; Mr. R. Giffen, from the excess of export over import, takes it at about 1,000,000*l.* per year. This is important, because, from the absence of statistics, China is not included in Dr. Soetbeer's estimate.

Many of the Asiatic islands, and especially Japan, have in the aggregate yielded a considerable amount of gold, and will probably continue to do so; but from the point of view in which we are now considering the question these areas need not detain us. Here, as in Africa, the reputed production during Portuguese rule is vastly in excess of what, apparently, can be raised now.

South America and Mexico.—It is of some importance to obtain a fairly correct estimate of the yield of South America and Mexico, because it is on all hands allowed to be large. The differences in the estimates of Sir Hector Hay and Dr. Soetbeer are chiefly due to different figures for these districts, Sir Hector Hay's being much the lower as regards silver, and slightly lower as regards gold.

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[1] See Professor V. Ball's *Coal, Iron, and Gold Mines of India*, and his lecture to the Geologists' Association, *Mining Journal*, June 12, 1886.

There is some convenience in classing Mexico with South America, because together they contain the older goldfields of the western hemisphere, the chief source of the precious metals from the discovery of America to the development of the Russian and Siberian goldfields.

The annual yield of gold in the *United States of Columbia* is thus approximately given by Dr. Soetbeer:—

	£		£
1851–1860	483,000	1869–1881	621,000
1860–1863	395,000	1881–1882	798,000
1863–1869	496,000		

It therefore ranks between New South Wales and New Zealand.

Gold occurs here in lodes cutting through rocks of all ages from pre-Cambrian to Cretaceous, and under many varieties of condition and purity.

The rapid development of gold mines in *Venezuela* is shown in the following table:—

	£
1866 to end of 1879	3,080,100
1880	467,100
1881	475,100
1882	554,000
1883	716,600
1884	937,700
1885	688,100
1886	796,800
	7,715,500

Of this amount El Callao alone has produced 4,175,000*l.* Of the gold raised in 1886, 83 per cent. came from this mine. All accounts agree as to the gold resources of Venezuela, but with the notable exception just mentioned few of the mines have as yet been successful.

The yield of *French Guiana* averages about 240,000*l.* yearly; this is all alluvial gold. *Dutch Guiana* produced about 70,000*l.* in gold in 1879; gold mining commenced here only in 1875.

Gold is known to occur in *British Guiana*, but very little has been done to work it. Something may be done here when the political questions are in a more settled state.

Brazil yielded a great deal of gold in the last century, when the rich placers were discovered. As these were worked out the field fell, and the produce now is very largely from quartz-mining. The period of maximum productiveness was from about 1730 to 1750. In some of these years it is supposed that about 5,000,000*l.* of gold were raised; but the average production must have been much below this. It fell to an average of 50,000*l.* from 1800 to 1840; rose to 250,000*l.* or 300,000*l.* between 1840 and 1860, and then rapidly fell; in 1870 and for a short time after it is believed to have fallen to 5,000*l.*[1]

With the development of vein-mines the gold production of Brazil rapidly rose, largely in consequence of the St. John del Rey mines. But of late years it has declined in consequence of a series of misfortunes at these mines. In 1879 the production of the *Minas Geraes* district w a about 235,000*l.* The yield was estimated at about 155,000*l.* in 1881 and 1882, and at about 132,000*l.* in 1883 and 1884.

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[1] These figures are from Del Mar, *Hist. of the Precious Metals*, 1880, p. 123.

The estimates for the total production of gold in Brazil, from the first working of the placers (about 1680) to 1880, give from 145,000,000*l.* (Soetbeer) to 180,000,000*l.* (Del Mar); one-tenth, or less, being from vein-mining. The remaining South American States, including *Peru*, *Bolivia*, and *Chili*, probably produce about 100,000*l.* yearly.

Mexico is chiefly known as the great source of silver, but its gold produce is of some importance.

In 1878 the yield was estimated at 207,000*l.*; it fell to 178,000*l.* in 1881, and rose to 245,000*l.* in 1884. The greater part of this is from veins —chiefly of auriferous quartz, but partly of gold with ores of other metals.

Europe (other than Russia).—It would be of great interest to trace the sources of the gold raised in Europe, and especially to discuss the production in times when Europe was largely dependent upon its own resources for its stock of gold. But this would carry us beyond the limits of our subject. Nor need we stay to describe in detail the production of each country. All the gold-bearing districts of Europe are well known, and there is no likelihood of any increased yield, save to some extent by the improved treatment of ores containing gold in small quantities. The recent increase in the gold of Germany is mainly due to this cause, many low-class sulphuretted ores from Australia being sent there for treatment.

The following are statistics of European gold:—

	1881[1]	1882	1883	1884
	£	£	£	£
Austro-Hungary . .	248,100	218,000	225,000	220,400
Germany	48,000	52,000	63,000	77,000
Italy	20,000	20,000	20,000	20,000
Turkey	1,025	1,380	1,460	1,460
Sweden	138	2,355	5,200	2,700
	317,263	293,735	314,660	321,560

Silver.—In the centuries immediately preceding the Christian era Spain and Greece yielded much silver. The Carthaginians, and after them the Romans, systematically worked the mines in Spain. The richest mine was that of Bebulo, the modern Guadalcanal, which for a time is supposed to have supplied Hannibal with 300 lbs. of silver per day.[2]

In Greece the richest mines were those of Laurium (argentiferous galena), which M. Cordella, judging from the slags and waste-heaps, believed to have produced about 2,100,000 tons of lead, and over 18,000,000 lbs. of silver.[3]

On the revival of mining in the seventh and eighth centuries the

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[1] The French official mineral statistics make a return of gold for France:—4,300*l.* in 1880; 5,356*l.* in 1881. The ores from which it was obtained were probably, in part at least, derived from foreign sources.—J. A. Phillips, *Ore Deposits*, p. 232.

[2] Del Mar, *Hist. of the Precious Metals*, p. 23.

[3] The most interesting instance of re-working old slags and mine-waste is that at Laurium. The slags here contain from $5\frac{1}{2}$ to 14 per cent. of lead, whilst many ancient slags in Spain and Italy contain 25 per cent. From these old Laurium

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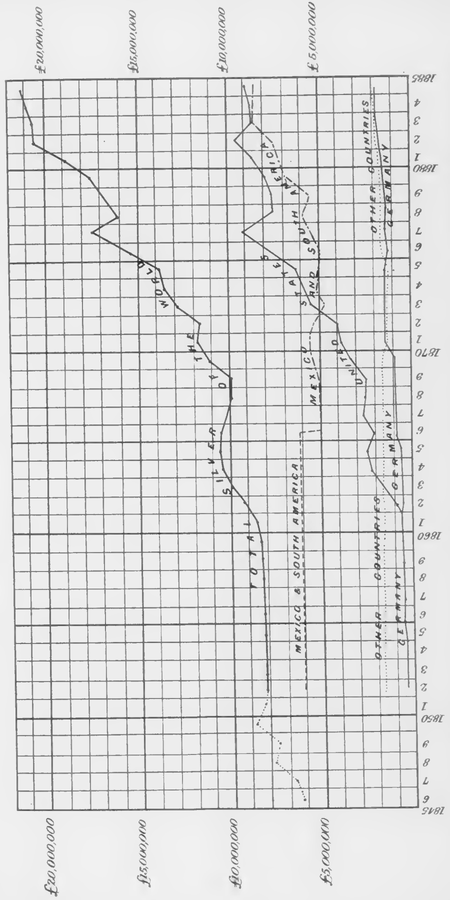
TABLE IV.

SILVER PRODUCTION OF THE WORLD



Illustrating Mr. William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

silver mines of Spain were re-worked by the Arabs. Mines in Germany were opened which, until recently, have continued to yield a good supply. During the six or eight centuries preceding the discovery of America, Spain and Germany yielded the greater part of the silver of Europe.

With the discovery of the New World large supplies of silver were poured into Europe, chiefly from Mexico and Peru. At a later date Chili and Bolivia became great silver-producing countries; from all these a steady supply still comes, and is likely to come.

With the discovery in 1859 of the Comstock, in Nevada, the United States rapidly rose into importance as a silver-producing country. About 1873 the production of the United States equalled that from the older silver areas of Mexico and South America, and afterwards, for a time, exceeded it.

Rich silver-bearing districts were discovered in Colorado, Utah, and Arizona, the yield from which helped to balance the rapid fall in Nevada. But the total production of the United States has of late years only slowly increased, whilst that from Mexico and South America has been steadily and more rapidly rising, so that now the older silver areas of the New World again stand at the head of the list.

Silver is almost entirely obtained from veins or from irregular masses associated with veins. The main exception to this is the silver contained in copper ore, which sometimes is disseminated through bedded rocks, the best example of which is the copper slate of Mansfeld.

The veins may be roughly divided into those of true silver ore, argentiferous lead ore—chiefly galena, and various argentiferous ores of copper. So various in character are the veins, their relation to the enclosing rock, and the nature of the ores, that no useful purpose would be served by touching upon these questions here; they are fully discussed in Phillips' 'Ore Deposits' (1884), to which work those wishing information on the subject should refer.

One point, however, is of so much importance to our subject that attention must be especially directed to it—that is, the exceptional nature of many of the great silver deposits of the United States. These have been already briefly referred to, and it was pointed out that whereas lodes often retain their productiveness to indefinite depths, these rich bonanzas and chambers of ore are very irregular in their occurrence, and are unlikely to continue productive to great depths or for long distances.

It is possible that other deposits resembling the Comstock may exist, and may some day be worked; also that other rich deposits like those of Leadville may be found; from which large quantities of silver ore or silver-lead ore may be obtained. But the expectation often expressed that such mines will become common and will flood the world with silver is quite unwarranted. If the United States is to keep at anything like its present production, the discovery of some such rich deposits is needful to balance the loss of those now becoming exhausted; as the mines are deepened the working expenses greatly increase, whilst not unfrequently (unlike the majority of gold-quartz mines) the productiveness of the lode diminishes.

At the time of the Comstock's maximum yield very little silver was

slags and waste-heaps, and also from some ore freshly raised, the production of lead has been from 7,000 to 10,000 tons yearly, with from 8*l.* to 14*l.* of silver per ton of lead. Over 1,000,000*l.* in lead and silver have been produced from the Laurium mines since they were reopened in 1864.

obtained in the United States beyond the limits of Nevada; but now there are seven States each producing $3,000,000 and upwards per year; two States each produced over $10,000,000 in 1883.

The following table gives the production for the years 1880–85 in thousands of dollars: 750 = $750,000.[1]

	1880	1881	1882	1883	1884	1885
California	1,151	750	845	1,460	3,000	2,500
Colorado	16,550	17,160	16,500	17,370	16,000	15,800
Nevada	12,430	7,060	6,750	5,430	5,600	6,000
Utah	4,743	6,400	6,800	5,620	6,800	6,750
Montana	2,905	2,630	4,370	6,000	7,000	10,060
Arizona	2,326	7,300	7,500	5,200	4,500	3,800
Idaho	464	1,300	2,000	2,100	2,720	3,500
New Mexico	392	275	1,800	2,845	3,000	3,000
Other States	150	125	235	175	180	190
Total	41,111	43,000	46,800	46,200	48,800	51,600

Canada.—The beautiful silver ores from near Lake Superior, exhibited in the Canadian Court of the Colonial and Indian Exhibition, naturally led many people to think highly of this district as a probable source of silver; such expectations have been quite recently revived. Dr. T. Sterry Hunt, to whom the whole district is well known, informs us that, although in places remarkably rich, the lodes are not continuously productive. Many attempts have been made to work them, but without success. Silver Islet, near Port Arthur, has yielded the largest amount of ore. Dr. Selwyn states[2] that this was worked at intervals from 1869 to 1884, and produced a total of about $3,000,000. The lode was followed to the depth of 1,230 feet, and the mine was then abandoned.

Great uncertainty exists as to the actual amount of silver produced in *Mexico and South America*, but on all hands it is allowed to be large. In 1800 these countries gave about 91½ per cent. of the world's production, Mexico alone giving 61½ per cent. In 1850 they gave 82½ per cent.; Mexico, 58½. In 1865, 63 per cent.; Mexico, 42.[3] In 1883, 41¼ per cent.; Mexico, 26. The relative importance of Mexico and South America have, therefore, declined, but their actual output has increased.

The production of silver in *Germany* has steadily increased during the last thirty years, but this is due to the great development of metallurgical works, to which, from all parts, are sent low-grade ores of gold and silver and ores of other metals containing small quantities of them. It is not due to output from the local mines, for silver mining in Germany is generally in a very depressed state. Some Government mines, notably those of the Harz, are kept going at a loss in order to provide employment for the large population dependent upon them.

The silver produce of *Norway* is now valued at about 50,000*l.* per year, which was the average of the years 1834 to 1864. The production in the period here mentioned varied much, the largest returns being 87,558*l.* in 1834 and 84,356*l.* in 1858; the smallest 36,772*l.* in 1845 and 26,708*l.* in 1862.

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[1] The total production for 1886 is $51,000,000.

[2] Catalogue of Economic Minerals of Canadian, Col. and Ind. Exhib. 1886, p. 51.

[3] These figures are from Phillips' *Gold and Silver*, 1867, p. 320.

The estimates for *Spain* are very untrustworthy, but it is believed that of late years the annual production of silver has been from 600,000*l.* to 650,000*l.*, a considerable proportion of which is from argentiferous galena.

A singular instance of the discovery of a rich silver lode in a country long explored is that of Hiendelaencina, in Spain. In 1843 a native of the district who had worked in the mines of Mexico noticed the resemblance of a block of stone to the ores with which he was familiar. The result was the discovery and opening up of the richest modern mines in Spain. From 1846 to 1866 they yielded 631,544 lbs. troy of silver, but their production since 1858 has been small.[1]

Reference has already been made (p. 13) to the growing importance of *New South Wales* as a silver-producing country.

The relative amounts of silver produced directly from true silver ores and those obtained by treating ores of other metals is a point of much interest. It was carefully worked out by Professor W. C. Roberts-Austen, in his evidence before the Gold and Silver Commission, 1887 (First Report, p. 325). He gives the following figures for the year 1883, with an estimate of the cost per oz. of silver by each process:—

			Oz.	Cost per oz. s.	d.
Treatment of silver ores			49,920,733	1	5
Desilverisation of lead	United States	21,890,000	30,726,000	2	0
	Europe	8,036,000			
	Elsewhere	800,000			
Desilverisation of copper and cupriferous products	Mansfeld	2,382,000	7,200,000	1	11
	Great Britain	328,000			
	Elsewhere	4,490,000			
Refining of native gold			508,000	0	2½
	Total		88,354,733	Mean 1	8

Conclusion.—In taking a general review of the goldfields likely in the near future to yield the most constant supply, it is evident from Table I. that an important place must be given to Russia. With a very slight fall in the produce of Australia and of the United States, Russia would again take her old place at the head of gold-producing countries. With its enormous areas of placer gold only partially worked, and its Siberian veins untouched, a steady yield of gold may be anticipated for many years to come.

The United States and Australasia have of late years been running very closely together, Australia being slightly in excess. In the former there is now a slight tendency to rise in yield.[2] A permanent rise cannot safely be anticipated; a more steady yield than in past years is all that can be hoped for; and this it seems likely may be the case, largely due to quartz-mining. The rapid fall in the gold produce of the United States from 1877 to 1883 was chiefly due to the decrease of silver-mining in the Comstock district, about 40 per cent. of the value here being gold. If we deduct the silver-gold, as is done on Tables I. and II., we see that the fall from 1877 was a very gradual one. The vast placer deposits of California, now in great part sealed by repressive legislation, will be to some extent again worked, either by drift-mining or by hydraulicking with provision for the retention of the débris. Table III. shows a gradual steadying of the produce of Australasia, neither placer nor quartz mining varying much from 1880 to 1885.

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[1] Phillips and Bauerman, *Metallurgy*, p. 665.

[2] Since this was written the United States statistics for 1886 have appeared. The yield of gold for the last four years is stated as follows:—1883, $30,000,000; 1884, $30,800,000; 1885, $31,801,000; 1886, $35,000,000.

Of the newer goldfields the first place should probably be given to Venezuela, &c. The wealth of this country in gold-quartz is well established; but we may perhaps expect for a time a greater development of alluvial-mining.

South Africa is generally looked upon with favour as a source from whence our future supply of gold may in part be drawn. Without doubt there are here rich lodes, and it would be strange if this country were destitute of rich placers; though of this there is as yet but little evidence. From these sources mines may possibly be worked at a profit which will give a steady yield of gold; but there is as yet no evidence that the yield will be sufficient in amount to materially influence the world's production.

As regards India the prospect is still less hopeful. That large quantities of gold were raised here by the native princes in times preceding the British rule is tolerably certain; but it is probable that this large production was spread over long periods of time, and certainly it was raised under conditions—of forced labour, &c.—which are not now applicable.

It is unlikely that India will ever contribute to the world's stock sufficient native gold to materially influence the total production. A far more important point is the amount of gold hoarded in India, and the probability or otherwise of that being some day set free. Most estimates concerning gold are ludicrously vague, but on the question of the amount hoarded vagueness is unavoidable. It is known that 130,000,000*l.* of gold has been taken into India since 1835;[1] practically none of this is in circulation (silver being the standard and the coinage of India). How much was hoarded in the centuries preceding 1835 no one can say. If it only equals the amount hoarded since, we have 260,000,000*l.*, or nearly thirteen times the world's present annual production. The original source of this gold and the ways by which it reached India would be an interesting subject for inquiry. Since 1851 it is the gold of the world, mainly sent through England; but in the long past times it was probably in part of native production, in part the gold of Europe, sent over the old trade routes in return for the manufactured articles of India. It is supposed that at least as much silver is hoarded in India as gold. If so the value of silver and gold hoarded in India since 1835 nearly equals in value one-third of the total amount of gold and silver coin now in circulation in the world.

Famines set free some of this gold, and we may perhaps anticipate that the diffusion of Western ideas will free more, but it is unlikely that gold will come from this source in sufficient quantities to influence the annual production of the world.

British Columbia may possibly increase its yield. Other countries (as yet little known), as Equatorial Africa, Borneo, and North China, may add somewhat to the world's stock. A steady though comparatively small supply may be looked for from the treatment of silver ores and from the auriferous ores of other metals. In all parts of the world an increased supply is assured by improved methods of mining, milling, and metallurgy; this will be obtained by an actual increase from ore now worked, and also from ores of lower grade, made profitable by the improved methods; whilst tailings, &c., of former times can in some cases be profitably worked over again.

But for all practical purposes the chief sources will probably continue to be the goldfields of the United States, of Australasia, and of Russia, aided by the development of the goldfields of South America. Everything points to a steady production from the three areas first named, and to an increased yield from the last.

As regards the future production of silver it is more difficult to suggest any forecast. It is less a question of where the silver is than of the price at which silver can be sold. The depreciation of silver may be in part due to increased production; but it is due, in at least an equal degree, to changes in the currency of certain nations setting free silver previously absorbed in coinage. If from either cause, or from both combined, the price of silver falls, many mines will cease working; if the price of silver rises, the mines will be reopened and other mines will be developed; and with mines which remain at work ores of low grade may be passed over or stored at low prices, which can be quickly sent into the market if prices rise. So far, therefore, as the natural supply of silver is concerned, the price and the rate of production will react on each other, with a tendency to steady both supply and price.

The natural sources of silver are large and widely spread, and will continue to yield a sufficient supply for many years to come. If the price of silver were to rise Mexico and South America alone could produce all that the world wants. The yield from the United States will continue. But there is no reason to expect a great increase in the world's production, and, from this cause, a continued fall in price.

Professor Roberts-Austen has shown (see p. 23) that only about 57 per cent. of the world's silver is now produced from true silver ores; the rest is obtained in the metallurgical treatment of other ores in which silver is a more or less important constituent. These ores will continue to be worked for the other metals which they contain, and a steady supply of silver is thus assured. But the price of silver will necessarily exert an important influence upon these works; a slight rise in price will enable many ores to be worked which are now lying untouched, and here again price and supply will act upon and steady each other.

Silver-mining in its various modifications—and the same remark applies to gold obtained from silver ores—may be ranked with metal-mining in its ordinary conditions. Mines which are hopelessly bad will be abandoned; those which are on the verge of paying will be persevered with in hopes of better yield or higher price. In all metal-mining there is far too much gambling and wild speculation, and it is doubtful if, taking metal-mining all round, the value raised equals the expenses. But gold-mining cannot be ranked with ordinary mining. There is a glamour about gold which blinds men to ordinary prudential considerations. The wildest schemes meet with willing supporters, and money is always forthcoming to develop the poorest mines and to keep them going upon the most shadowy of hopes.

Enormous fortunes have been made in gold-mining by a few lucky speculators. But for one who has been thus fortunate there are scores who have lost heavily.

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[1] Mr. D. M. Barbour. First Report of the Gold and Silver Commission, 1887, pp. 57–62. See also Dr. Soetbeer's *Materialien*, and Memorandum by Mr. R. H. Inglis Palgrave, in Third Report of Royal Commission on Depression of Trade, 1886.

The facts which we have been considering as to the probable future of gold-mining warrant us in believing that the industry will gradually make for itself a sounder and more honest position. But there must ever be great uncertainty, and therefore a wide field for speculation and for dishonest dealing.

If a steady and undiminished production of gold is essential for the well-being of the world, perhaps what we have most to dread is a sudden influx of common-sense and prudence in the investing public; for this would at once close a great number of mines, and might considerably diminish the world's production. But probably this contingency is sufficiently remote to be safely left out of consideration.

Tables I., II., and III. are, for the years 1852 to 1885, based on the estimates of Sir Hector Hay. These are taken because they give the probable production for each year; Dr. Soetbeer's figures before 1876 give only averages of five years. From 1870 to 1880 Sir Hector Hay's estimates for silver are from 8 to 25 per cent. lower than those of Dr. Soetbeer, chiefly due to differences in Mexico and South America; for gold in the same period they are from 3 to 10 per cent. lower. The differences are greater in the first half of these ten years than in the second half. Before 1870 the differences in the two estimates were comparatively small for silver, but were rather larger for gold. From 1880 the estimates more nearly agree, but Sir Hector Hay's are still rather the lower,

Table IV. (Australasia) is taken from official figures supplied for the 16th Ann. Report of the Deputy Master of the Mint (1886). It differs somewhat from the corresponding diagram in Table I.

The proportions of vein gold to alluvial gold at different periods are taken from a variety of sources. In recent years the estimates are fairly trustworthy, but for former years they are necessarily vague. The proportion of gold in the silver of the United States is taken from the Appendix, by L. A. Garnett, to Bowie's 'Hydraulic Mining.'

The authorities cited throughout this paper have been consulted upon the question generally and not solely for the statements especially referred to. Information has also been obtained from numerous other sources, amongst others from Lock's 'Gold' (1882), the fullest treatise upon that subject, which also contains a lengthy Bibliography; Hague's 'Mining Industries at the Paris Exhibition, 1878'; J. A. Phillips' 'Mining and Metallurgy of Gold and Silver' (1867); Percy's 'Metallurgy of Silver'; the various Catalogues and Guides for the Colonial and Indian Exhibition of last year; Dr. C. Le Neve Foster's 'Report on the Mining Industries of the British Colonies'; Report (in the 'Mining Journal') by R. Etheridge, jun., and T. Davis upon the exhibits; Reports (also in the 'Mining Journal') of Conferences of the Geologists' Association at the Exhibition. Gold was especially referred to in the lectures by Professor V. Ball (India), Dr. Selwyn (Canada), Sir J. von Haast (New Zealand), Mr. F. W. Rudler (Australia). Jervis, 'Del Oro in Natura' (1881), gives a table showing, in kilog. and in oz. troy, the produce of various districts from 1848 to 1879. Suess' 'Die Zukunft des Goldes' (1877) contains a Bibliography.

I have also to thank Dr. T. Sterry Hunt and Mr. F. W. Rudler for much assistance and information.

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

31285

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